Perception as Relational Structure: An Empirically Grounded Axiomatic Framework

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Abstract

Recent empirical work across psychophysics, neuroscience, cognitive science, developmental psychology, linguistics, and physics increasingly supports the view that perception is fundamentally relational rather than object-based. This paper develops a unified axiomatic framework that systematizes this convergence. Four axioms are introduced: (1) perceptual experience consists only of relational contrasts; (2) intrinsic boundaries never appear in the perceptual field; (3) thinghood is constructed through cognitive operations involving memory, grouping, and expectation; and (4) division of experience into discrete parts arises only through symbolic systems such as language and measurement. From these axioms, eight theorems follow, demonstrating that objecthood is not a perceptual primitive but a secondary construction derived from cognitive and symbolic processes. The empirical integration section shows that this framework is consistent with findings in contrast-based psychophysics, receptive-field neuroscience, predictive processing, infant development studies, unsupervised computational models, linguistic categorization, and the continuity of physical field theories. Philosophically, the framework clarifies the limits of perceptual givenness, the relation between perceptual and symbolic ontologies, and the status of scientific representation. It offers a unified interpretation of why perception appears object-like despite being generated from contrast-based, continuous relations. The resulting view strengthens relational, structural, and ecological approaches to perception while providing a principled formal foundation for debates about perceptual content, segmentation, and the construction of boundaries.

1 Introduction

Research in cognitive science and philosophy of perception often begins with the assumption that objects are the primary units of perceptual experience. Everyday introspection seems to confirm this: we see discrete objects with edges, boundaries, and surfaces. Classical computational theories of vision, such as Marr's three-stage model, treat object segmentation as an essential early step in perceptual processing. Gestalt psychology posits innate principles that organize sensations into objects. Developmental psychology frequently interprets infant behavior as evidence that object-based expectations are present early in life. Much of contemporary philosophy of mind also assumes that perceptual content is organized around discrete entities.

Yet these assumptions sit in tension with empirical findings across numerous scientific fields. Psychophysics consistently shows that perception is driven by contrasts rather than absolute values. Neuroscience reveals that receptive fields encode gradients and relational differences, not intrinsic boundaries. Predictive-processing models describe perception as the outcome of hierarchical

inference rather than feature-based assembly. Developmental evidence suggests that object segmentation is learned gradually and depends on cultural and linguistic contexts. Linguistic research demonstrates that segmentation of color, space, and objects varies across languages, challenging the idea that object boundaries are perceptually given. Physics describes the world in terms of continuous fields and non-separable interactions rather than discrete, intrinsically bounded entities.

Taken together, these findings suggest a different starting point: perceptual experience is relational and continuous, with objects arising secondarily through cognitive and symbolic operations. However, despite growing empirical convergence, there remains no unified theoretical framework that integrates these insights into a single coherent account.

This paper proposes such a framework. The central claim is that perceptual content is composed entirely of relational contrasts within a continuous field. This is formalized through an axiomatic system that distinguishes among the perceptual, cognitive, and symbolic levels of processing. The axioms capture constraints revealed by empirical studies, while the theorems derive consequences for objecthood, boundaries, separateness, and symbolic structuring. The framework is not intended as a metaphysical theory of reality but as a formal description of the structure of perceptual experience as established by empirical investigation.

The manuscript proceeds as follows. Section 2 reviews empirical evidence from multiple disciplines supporting the relational and continuous nature of perception. Section 3 presents the formal definitions and axioms. Section 4 derives eight theorems, each showing how objecthood and division arise only through cognitive or symbolic layers. Section 5 demonstrates how the framework synthesizes findings from psychophysics, neuroscience, development, linguistics, and physics. Section 6 outlines the philosophical implications for perceptual content, representationalism, scientific modeling, and structural realism. Section 7 addresses major objections. The conclusion summarizes the contributions and outlines future research directions.

2 Background and empirical foundations

This section reviews empirical research that motivates the axioms. Evidence across disciplines points toward four central themes: (1) perception is contrast-based; (2) intrinsic boundaries are not encoded in the sensory signal; (3) objecthood emerges through learning and memory; and (4) symbolic systems influence segmentation.

2.1 Psychophysics: contrast and relational structure

Psychophysical results demonstrate that perceptual systems respond to relational changes rather than intrinsic properties. The Weber–Fechner law states that perceptual discrimination depends on proportional differences, not absolute magnitudes. Uniform stimulation leads to perceptual fading, as shown in Ganzfeld experiments, indicating that perception requires contrast variability. Mach bands illustrate illusory boundaries created by contrast gradients, not by intrinsic edges. These phenomena show that what appears as an "edge" is a relational construction arising from local differences in stimulation.

2.2 Neuroscience: gradients, receptive fields, and population coding

Neural receptive fields in vision and other modalities encode differences across space and time. Lateral inhibition produces enhanced responses at points of contrast, not intrinsic boundaries. Population coding distributes information across neuronal ensembles, representing relational structures rather than discrete objects. Predictive-processing theories further suggest that perceptual content results from hierarchical inference, where predictive error signals reflect relational discrepancies between expectation and sensory input.

2.3 Developmental psychology: learning boundaries and objects

Infant studies reveal that segmentation into objects is not innate but emerges gradually through interaction, learning, and cultural exposure. Experiments on object permanence, object individuation, and the use of spatiotemporal versus featural cues show that perceived objecthood develops in stages and depends on cognitive resources. Cross-cultural studies indicate variability in how children learn to segment and categorize, suggesting that object-based perception is not purely perceptual but heavily shaped by cognitive and symbolic scaffolding.

2.4 Cognitive science: computational and inferential processing

Computational models of vision increasingly adopt relational or feature-agnostic approaches. Texture segmentation, structural description theories, and predictive coding frameworks emphasize relational patterns rather than object primitives. Unsupervised deep learning models can generate relational representations without forming discrete object categories unless trained with symbolic labels, suggesting that objecthood is not a default outcome of perceptual processing.

2.5 Linguistics: symbolic segmentation and categorical perception

Language influences perceptual segmentation through categorical perception. Differences in color terms lead to different perceptual boundaries across linguistic communities. Spatial terms, classifiers, and noun categories shape how continuous fields are partitioned. Linguistic labeling sharpens or creates boundaries that did not appear prior to symbolic segmentation. These findings motivate Axiom 4: division is symbolic.

2.6 Physics: continuity and non-separability

Physical theories describe reality in terms of continuous fields, such as electromagnetic and gravitational fields, and in terms of non-separable quantum states. Objects with intrinsic boundaries do not appear in fundamental physical descriptions. Apparent discreteness arises through measurement or coarse-graining, analogous to symbolic discretization in perception. Thus, continuity at the base physical level aligns with the continuity at the perceptual level.

3 Formal definitions and axiomatic structure

This section presents the formal vocabulary for the axiomatic system.

3.1 Definitions

Perceptual field The total sensory manifold as directly experienced, prior to cognitive or symbolic interpretation.

Relational content Any perceptible contrast or difference across the perceptual field, including variations in intensity, frequency, texture, color, motion, or temporal change.

Intrinsic boundary A discontinuity that would exist in the perceptual field independently of memory, expectation, or symbolic categorization.

Thinghood The cognitive attribution of unity, identity, and persistence to a region of experience, enabling it to be treated as an object.

Symbolic system Any representational scheme—linguistic, numerical, or categorical—that discretizes continuous experience.

Division Segmentation of the perceptual field into discrete parts by cognitive or symbolic means.

Isolation A condition in which a region of experience is separated from its surroundings by intrinsic boundaries.

Continuity The absence of intrinsic partitions within the perceptual field.

3.2 Axioms

Axiom 1 (Perception is relational). All discriminable perceptual content consists of relational contrasts. Without relational variation, no perception occurs.

Axiom 2 (No intrinsic boundaries). The perceptual field contains no intrinsic boundaries. Apparent boundaries arise from relational contrasts, not independent dividers.

Axiom 3 (Thinghood is constructed). Objects do not arise at the level of raw perception. Thinghood depends on memory, grouping, and categorization.

Axiom 4 (Division is symbolic). Division into parts is imposed by symbolic systems such as language and measurement.

4 Derived theorems

Theorem 1. Objecthood cannot arise from perception.

Proof. Perception consists of relational content (Axiom 1). Objecthood requires boundaries. Intrinsic boundaries do not appear in perception (Axiom 2). Therefore, perception alone cannot yield objecthood. □

Theorem 2. All boundaries are symbolic constructs.

Proof. Boundaries require intrinsic discontinuities. Axiom 2 denies such discontinuities. Axiom 4 states that division is symbolic. Therefore all attributed boundaries are symbolic. □

Theorem 3. Division is not perceptual.

Proof. Division presupposes boundaries. Boundaries do not appear in perception (Axiom 2). Thus, division is imposed by symbolic systems (Axiom 4). □

Theorem 4. The perceptual field is continuous.

Proof. Continuity is defined as absence of intrinsic partitions. Axiom 2 directly entails continuity. □

Theorem 5. Separateness is cognitive-symbolic.

Proof. Separateness requires both objecthood and boundaries. Boundaries are symbolic (Theorem 2), and thinghood is constructed (Axiom 3). Thus separateness is cognitive-symbolic. □

Theorem 6. Symbolic systems reify abstractions.

Proof. Symbolic systems partition continuous relational fields into labeled units (Axiom 4). Labeled regions acquire the appearance of discrete entities. □

Theorem 7. Isolation cannot be observed.

Proof. Isolation requires intrinsic boundaries. Axiom 2 denies such boundaries anywhere in the perceptual field. Hence isolation is unobservable. □

Theorem 8. Perceived objects are secondary constructions.

Proof. Objecthood requires both thinghood and boundaries. Thinghood is constructed (Axiom 3), boundaries are symbolic (Theorem 2). Therefore perceived objects are secondary constructions. □

5 Empirical integration

This section shows how the axioms-and-theorems framework aligns with empirical data.

5.1 Vision science and psychophysics

Contrast-based effects such as Mach bands support Axiom 1. The visual system enhances differences across regions, producing illusory boundaries where none exist. Edge detection algorithms similarly rely on gradient changes rather than intrinsic features. Uniform-field experiments that lead to perceptual fading show that perception cannot occur without relational variability.

5.2 Neuroscience and predictive processing

Neural receptive fields encode gradients and relational differences rather than intrinsic boundaries. Predictive-processing models explain perception as hierarchical inference, where errors represent deviations from expected relational patterns. This fits the axioms by treating perceptual content as relational and by denying intrinsic discontinuities.

5.3 Developmental evidence

Infants do not initially perceive discrete objects. Object individuation and segmentation develop through learning, depending on memory, expectation, and culturally mediated symbolic systems. This supports Axiom 3 and suggests that apparent objecthood is learned rather than given.

5.4 Linguistic shaping of segmentation

Language divides continuous fields through naming and classification. Categorical perception demonstrates that linguistic boundaries reshape perceptual discrimination. Languages that partition color space differently show different perceptual boundaries. These findings support Axiom 4 and Theorem 2.

5.5 Computational models

Unsupervised neural networks trained on raw sensory input do not form object categories unless symbolic labels are introduced. Models that rely on relational encoding succeed without explicit

object representations. This supports the claim that objecthood is symbolic or conceptual, not perceptual.

5.6 Physics and continuity

Physics describes the world as composed of continuous fields and non-separable relational structures. Apparent discrete objects arise from coarse-graining and measurement, not intrinsic properties. This parallels Theorem 4 and suggests a deep structural alignment between perceptual and physical descriptions.

6 Philosophical implications

6.1 Relational theories of perception

The framework strengthens relational theories by grounding them empirically. Perception does not present discrete objects but continuous relations. This challenges object-based representationalism and supports ecological and structural approaches.

6.2 Limits of perceptual givenness

If perception yields relations rather than objects, then what is "given" in experience is not the world segmented into things but a continuous field structured by contrasts. Object-based content enters only through cognitive and symbolic layers.

6.3 Scientific representation

Scientific models that rely on discrete entities can be understood as symbolic discretizations of continuous relational fields. This aligns scientific modeling with perceptual and linguistic segmentation.

6.4 Structural realism

The framework supports structural realism by showing that both perception and physics point toward relational continuity rather than intrinsic objecthood.

7 Objections and replies

7.1 Objection: Neural edge detectors imply intrinsic boundaries.

Reply: Neural edge detectors compute contrast, not intrinsic edges. Their outputs depend on relational changes, not on intrinsic discontinuities in the stimulus.

7.2 Objection: Gestalt principles show boundary perception is innate.

Reply: Gestalt effects operate on relational configurations, not intrinsic boundaries. They reveal organizational tendencies, not perceptual primitives of objecthood.

7.3 Objection: Infants perceive objects before language.

Reply: Infant studies show sensitivity to relational cues, not full objecthood. The development of stable object representations requires memory and conceptual resources.

7.4 Objection: Action requires segmented objects.

Reply: Agents can interact with relational fields without requiring intrinsic object representations. Sensorimotor contingencies operate on gradients and contrasts.

8 Conclusion

This paper has developed an empirically grounded axiomatic framework demonstrating that perception is fundamentally relational and continuous. Objects, boundaries, and separateness arise only through cognitive and symbolic processes. The framework synthesizes evidence across psychophysics, neuroscience, development, linguistics, computational modeling, and physics. Philosophically, it clarifies the nature of perceptual content, the limits of perceptual givenness, and the relation between perceptual and symbolic ontologies. Future work may extend this framework to multisensory integration, action-oriented models, and the development of relational artificial agents.

Figure 1: A continuous gradient with no intrinsic boundaries.

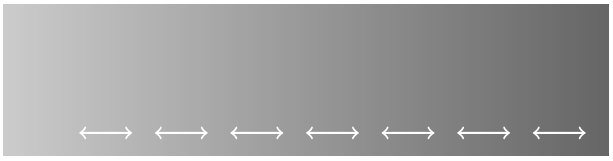

Figure 2: Arrows indicating contrast differences across the field.

A Diagram descriptions and figures

Figure 1: Sensory continuity

Figure 2: Relational encoding

Figure 3: Symbolic segmentation

Figure 4: Logical structure

Figure 3: Labels creating apparent partitions in a continuous field.

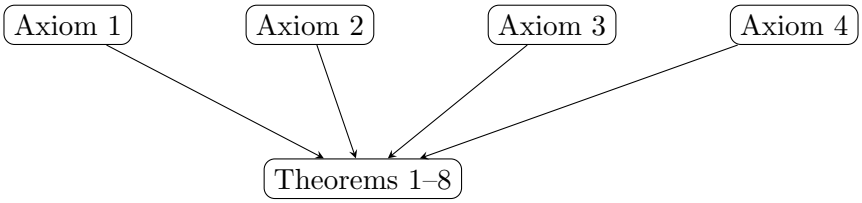

Figure 4: Logical dependencies among axioms and theorems.